Gobs of data

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Introduction

To transmit a data structure across a network or to store it in a file, it must be encoded and then decoded again. There are many encodings available, of course: JSON, XML, Google's protocol buffers, and more. And now there's another, provided by Go's gob package.

Why define a new encoding? It's a lot of work and redundant at that. Why not just use one of the existing formats? Well, for one thing, we do! Go has packages supporting all the encodings just mentioned (the protocol buffer package is in a separate repository but it's one of the most frequently downloaded). And for many purposes, including communicating with tools and systems written in other languages, they're the right choice.

But for a Go-specific environment, such as communicating between two servers written in Go, there's an opportunity to build something much easier to use and possibly more efficient.

Gobs work with the language in a way that an externally-defined, language-independent encoding cannot. At the same time, there are lessons to be learned from the existing systems.

Goals

The gob package was designed with a number of goals in mind.

First, and most obvious, it had to be very easy to use. First, because Go has reflection, there is no need for a separate interface definition language or “protocol compiler”. The data structure itself is all the package should need to figure out how to encode and decode it. On the other hand, this approach means that gobs will never work as well with other languages, but that's OK: gobs are unashamedly Go-centric.

Efficiency is also important. Textual representations, exemplified by XML and JSON, are too slow to put at the center of an efficient communications network. A binary encoding is necessary.

Gob streams must be self-describing. Each gob stream, read from the beginning, contains sufficient information that the entire stream can be parsed by an agent that knows nothing a priori about its contents. This property means that you will always be able to decode a gob stream stored in a file, even long after you've forgotten what data it represents.

There were also some things to learn from our experiences with Google protocol buffers.

Protocol buffer misfeatures

Protocol buffers had a major effect on the design of gobs, but have three features that were deliberately avoided. (Leaving aside the property that protocol buffers aren't self-describing: if you don't know the data definition used to encode a protocol buffer, you might not be able to parse it.)

First, protocol buffers only work on the data type we call a struct in Go. You can't encode an integer or array at the top level, only a struct with fields inside it. That seems a pointless restriction, at least in Go. If all you want to send is an array of integers, why should you have to put it into a struct first?

Next, a protocol buffer definition may specify that fields `T.x` and `T.y` are required to be present whenever a value of type `T` is encoded or decoded. Although such required fields may seem like a good idea, they are costly to implement because the codec must maintain a separate data structure while encoding and decoding, to be able to report when required fields are missing. They're also a maintenance problem. Over time, one may want to modify the data definition to remove a required field, but that may cause existing clients of the data to crash. It's better not to have them in the encoding at all. (Protocol buffers also have optional fields. But if we don't have required fields, all fields are optional and that's that. There will be more to say about optional fields a little later.)

The third protocol buffer misfeature is default values. If a protocol buffer omits the value for a “defaulted” field, then the decoded structure behaves as if the field were set to that value. This idea works nicely when you have getter and setter methods to control access to the field, but is harder to handle cleanly when the container is just a plain idiomatic struct. Required fields are also tricky to implement: where does one define the default values, what types do they have (is text UTF-8? uninterpreted bytes? how many bits in a float?) and despite the apparent simplicity, there were a number of complications in their design and implementation for protocol buffers. We decided to leave them out of gobs and fall back to Go’s trivial but effective defaulting rule: unless you set something otherwise, it has the “zero value” for that type - and it doesn’t need to be transmitted.

So gobs end up looking like a sort of generalized, simplified protocol buffer. How do they work?

Values

The encoded gob data isn't about types like `int8` and `uint16`. Instead, somewhat analogous to constants in Go, its integer values are abstract, sizeless numbers, either signed or unsigned. When you encode an `int8`, its value is transmitted as an unsized, variable-length integer. When you encode an `int64`, its value is also transmitted as an unsized, variable-length integer. (Signed and unsigned are treated distinctly, but the same unsized-ness applies to unsigned values too.) If both have the value 7, the bits sent on the wire will be identical. When the receiver decodes that value, it puts it into the receiver’s variable, which may be of arbitrary integer type. Thus an encoder may send a 7 that came from an `int8`, but the receiver may store it in an `int64`. This is fine: the value is an integer and as a long as it fits, everything works. (If it doesn’t fit, an error results.) This decoupling from the size of the variable gives some flexibility to the encoding: we can expand the type of the integer variable as the software evolves, but still be able to decode old data.

This flexibility also applies to pointers. Before transmission, all pointers are flattened. Values of type `int8`, `*int8`, `**int8`, `****int8`, etc. are all transmitted as an integer value, which may then be stored in `int` of any size, or `*int`, or `******int`, etc. Again, this allows for flexibility.

Flexibility also happens because, when decoding a struct, only those fields that are sent by the encoder are stored in the destination. Given the value

```
type T struct{ X, Y, Z int } // Only exported fields are encod
ed and decoded.
var t = T{X: 7, Y: 0, Z: 8}
```

the encoding of `t` sends only the 7 and 8. Because it's zero, the value of `Y` isn't even sent; there's no need to send a zero value.

The receiver could instead decode the value into this structure:

```
type U struct{ X, Y *int8 } // Note: pointers to int8s
var u U
```

and acquire a value of `u` with only `X` set (to the address of an `int8` variable set to 7); the `Z` field is ignored - where would you put it? When decoding structs, fields are matched by name and compatible type, and only fields that exist in both are affected. This simple approach finesses the “optional field” problem: as the type `T` evolves by adding fields, out of date receivers will still function with the part of the type they recognize. Thus gobs provide the important result of optional fields - extensibility - without any additional mechanism or notation.

From integers we can build all the other types: bytes, strings, arrays, slices, maps, even floats. Floating-point values are represented by their IEEE 754 floating-point bit pattern, stored as an integer, which works fine as long as you know their type, which we always do. By the way, that integer is sent in byte-reversed order because common values of floating-point numbers, such as small integers, have a lot of zeros at the low end that we can avoid transmitting.

One nice feature of gobs that Go makes possible is that they allow you to define your own encoding by having your type satisfy the GobEncoder and GobDecoder interfaces, in a manner analogous to the JSON package's Marshaler and Unmarshaler and also to the Stringer interface from package fmt. This facility makes it possible to represent special features, enforce constraints, or hide secrets when you transmit data. See the documentation for details.

Types on the wire

The first time you send a given type, the gob package includes in the data stream a description of that type. In fact, what happens is that the encoder is used to encode, in the standard gob encoding format, an internal struct that describes the type and gives it a unique number. (Basic types, plus the layout of the type description structure, are predefined by the software for bootstrapping.) After the type is described, it can be referenced by its type number.

Thus when we send our first type `T`, the gob encoder sends a description of `T` and tags it with a type number, say 127. All values, including the first, are then prefixed by that number, so a stream of `T` values looks like:

```
("define type id" 127, definition of type T)(127, T value)(127
, T value), ...
```

These type numbers make it possible to describe recursive types and send values of those types. Thus gobs can encode types such as trees:

```
type Node struct {
    Value       int
    Left, Right *Node
}
```

(It’s an exercise for the reader to discover how the zero-defaulting rule makes this work, even though gobs don’t represent pointers.)

With the type information, a gob stream is fully self-describing except for the set of bootstrap types, which is a well-defined starting point.

Compiling a machine

The first time you encode a value of a given type, the gob package builds a little interpreted machine specific to that data type. It uses reflection on the type to construct that machine, but once the machine is built it does not depend on reflection. The machine uses package unsafe and some trickery to convert the data into the encoded bytes at high speed. It could use reflection and avoid unsafe, but would be significantly slower. (A similar high-speed approach is taken by the protocol buffer support for Go, whose design was influenced by the implementation of gobs.) Subsequent values of the same type use the already-compiled machine, so they can be encoded right away.

[Update: As of Go 1.4, package unsafe is no longer use by the gob package, with a modest performance drop.]

Decoding is similar but harder. When you decode a value, the gob package holds a byte slice representing a value of a given encoder-defined type to decode, plus a Go value into which to decode it. The gob package builds a machine for that pair: the gob type sent on the wire crossed with the Go type provided for decoding. Once that decoding machine is built, though, it’s again a reflectionless engine that uses unsafe methods to get maximum speed.

Use

There’s a lot going on under the hood, but the result is an efficient, easy-to-use encoding system for transmitting data. Here’s a complete example showing differing encoded and decoded types. Note how easy it is to send and receive values; all you need to do is present values and variables to the gob package and it does all the work.

```
package main

import (
    "bytes"
    "encoding/gob"
    "fmt"
    "log"
)

type P struct {
    X, Y, Z int
    Name    string
}

type Q struct {
    X, Y *int32
    Name string
}

func main() {
```

```
func main() {
    // Initialize the encoder and decoder.  Normally enc and d
ec would be
    // bound to network connections and the encoder and decode

r would
    // run in different processes.
    var network bytes.Buffer        // Stand-in for a network
connection
    enc := gob.NewEncoder(&network) // Will write to network.
    dec := gob.NewDecoder(&network) // Will read from network.
    // Encode (send) the value.
    err := enc.Encode(P{3, 4, 5, "Pythagoras"})
    if err != nil {
        log.Fatal("encode error:", err)
    }
    // Decode (receive) the value.
    var q Q
    err = dec.Decode(&q)
    if err != nil {
        log.Fatal("decode error:", err)
    }
    fmt.Printf("%q: {%d,%d}\n", q.Name, *q.X, *q.Y)
```

```
    fmt.Printf("%q: {%d,%d}\n", q.Name, *q.X, *q.Y)
}
```

You can compile and run this example code in the Go Playground.

The rpc package builds on gobs to turn this encode/decode automation into transport for method calls across the network. That’s a subject for another article.

Details

The gob package documentation, especially the file doc.go, expands on many of the details described here and includes a full worked example showing how the encoding represents data. If you are interested in the innards of the gob implementation, that’s a good place to start.

Next article: Godoc: documenting Go code
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Blog Index

embed

package standard library

Version: go1.17.2 Latest |Published: Oct 7, 2021 |
License: BSD-3-Clause |Imports: 4 |Imported by: 3,109

Details

- Valid go.mod file
- Redistributable license
- Tagged version
- Stable version

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Repository

cs.opensource.google/go/go

Documentation

Overview

Package embed provides access to files embedded in the running Go program.

Go source files that import "embed" can use the

//go:embed directive to initialize a variable of type string, []byte, or FS with the contents of files read from the package directory or subdirectories at compile time.

For example, here are three ways to embed a file named hello.txt and then print its contents at run time.

Embedding one file into a string:

```
import _ "embed"

//go:embed hello.txt
var s string
print(s)
```

Embedding one file into a slice of bytes:

```
import _ "embed"

//go:embed hello.txt
var b []byte
print(string(b))
```

Embedded one or more files into a file system:

```
import "embed"

//go:embed hello.txt
var f embed.FS
data, _ := f.ReadFile("hello.txt")
print(string(data))
```

Directives

A //go:embed directive above a variable declaration specifies which files to embed, using one or more path.Match patterns.

The directive must immediately precede a line containing the declaration of a single variable. Only blank lines and ‘//’ line comments are permitted between the directive and the declaration.

The type of the variable must be a string type, or a slice of a byte type, or FS (or an alias of FS).

For example:

```
package server

import "embed"

// content holds our static web server content.
//go:embed image/* template/*
//go:embed html/index.html
var content embed.FS
```

The Go build system will recognize the directives and arrange for the declared variable (in the example above, content) to be populated with the matching files from the file system.

The //go:embed directive accepts multiple space-separated patterns for brevity, but it can also be repeated, to avoid very long lines when there are many patterns. The patterns are interpreted relative to the package directory containing the source file. The path separator is a forward slash, even on Windows systems. Patterns may not contain ‘.’ or ‘..’ or empty path elements, nor may they begin or end with a slash. To match everything in the current directory, use ‘*’ instead of ‘.’. To allow for naming files with spaces in their names, patterns can be written as Go double-quoted or back-quoted string literals.

If a pattern names a directory, all files in the subtree rooted at that directory are embedded (recursively), except that files with names beginning with ‘.’ or ‘_’ are excluded. So the variable in the above example is almost equivalent to:

```
// content is our static web server content.
//go:embed image template html/index.html
var content embed.FS
```

The difference is that ‘image/*’ embeds ‘image/.tempfile’ while ‘image’ does not.

The //go:embed directive can be used with both exported and unexported variables, depending on whether the package wants to make the data available to other packages. It can only be used with global variables at package scope, not with local variables.

Patterns must not match files outside the package's module, such as ‘.git/*’ or symbolic links. Matches for empty directories are ignored. After that, each pattern in a //go:embed line must match at least one file or non-empty directory.

If any patterns are invalid or have invalid matches, the build will fail.

Strings and Bytes

The //go:embed line for a variable of type string or []byte can have only a single pattern, and that pattern can match only a single file. The string or []byte is initialized with the contents of that file.

The //go:embed directive requires importing "embed", even when using a string or []byte. In source files that don't refer to embed.FS, use a blank import (import _ "embed").

File Systems

For embedding a single file, a variable of type string or []byte is often best. The FS type enables embedding a tree of files, such as a directory of static web server content, as in the example above.

FS implements the io/fs package's FS interface, so it can be used with any package that understands file systems, including net/http, text/template, and html/template.

For example, given the content variable in the example above, we can write:

```
http.Handle("/static/", http.StripPrefix("/static/"
, http.FileServer(http.FS(content))))

template.ParseFS(content, "*.tmpl")
```

Tools

To support tools that analyze Go packages, the patterns found in //go:embed lines are available in “go list” output. See the EmbedPatterns, TestEmbedPatterns, and XTestEmbedPatterns fields in the “go help list” output.

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type FS

  func (f FS) Open(name string) (fs.File, error)

  func (f FS) ReadDir(name string) ([]fs.DirEntry, error)

  func (f FS) ReadFile(name string) ([]byte, error)

Constants

This section is empty.

Variables

This section is empty.

Functions

This section is empty.

Types

type FS

```
type FS struct {
    // contains filtered or unexported fields
}
```

An FS is a read-only collection of files, usually initialized with a //go:embed directive. When declared without a //go:embed directive, an FS is an empty file system.

An FS is a read-only value, so it is safe to use from multiple goroutines simultaneously and also safe to assign values of type FS to each other.

FS implements fs.FS, so it can be used with any package that understands file system interfaces, including net/http, text/template, and html/template.

See the package documentation for more details about initializing an FS.

func (FS) Open

```
func (f FS) Open(name string) (fs.File, error)
```

Open opens the named file for reading and returns it as an fs.File.

func (FS) ReadDir

func (FS) ReadDir

```
func (f FS) ReadDir(name string) ([]fs.DirEntry,
error)
```

ReadDir reads and returns the entire named directory.

func (FS) ReadFile

```
func (f FS) ReadFile(name string) ([]byte, error)
```

ReadFile reads and returns the content of the named file.

Source Files

View all

embed.go

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Tutorials

How to Use go:embed in Go 1.16

Florin Pățan

June 9, 2021

One of the most anticipated features of Go 1.16 is the support for embedding files and folders into the application binary at compile-time without using an external tool. This feature is also known as go:embed, and it gets its name from the compiler directive that makes this functionality possible: //go:embed.

With it, you can embed all web assets required to make a frontend application work. The build pipeline will simplify since the embedding step does not require any additional tooling to get all static files needed in the binary. At the same time, the deployment pipeline is predictable since you don't need to worry about deploying the static files and the problems that come with that, such as: making sure the relative paths are what the binary expects, the working directory is the correct one, the application has the proper permissions to read the files, etc. You just deploy the application binary and start it, and everything else works.

Let’s see how we can use this feature to our advantage with an example webserver:

- First, create a new Go modules project in

GoLand, and make sure you use Go 1.16 or newer. The go directive in the go.mod file must be set to Go 1.16 or higher too.

```
module goembed.demo

go 1.16
```

- Our main.go file should look like this:

```
package main

import (
```

```go
	"embed"
	"html/template"
	"log"
	"net/http"
)

var (
	//go:embed resources
	res embed.FS

	pages = map[string]string{
		"/": "resources/index.gohtml",
	}
```

```
)

func main() {
    http.HandleFunc("/", func(w
http.ResponseWriter, r *http.Request) {
        page, ok := pages[r.URL.Path]
        if !ok {

w.WriteHeader(http.StatusNotFound)
            return
        }
        tpl, err :=
template.ParseFS(res, page)
```

```
        if err != nil {
            log.Printf("page %s not
found in pages cache...", r.RequestURI)

w.WriteHeader(http.StatusInternalServerE
rror)
            return
        }

        w.Header().Set("Content-Type",
"text/html")
        w.WriteHeader(http.StatusOK)
        data := map[string]interface{}{
```

```
            "userAgent": r.UserAgent(),
        }
        if err := tpl.Execute(w, data);
err != nil {
            return
        }
    })

    http.FileServer(http.FS(res))

    log.Println("server started...")
    err := http.ListenAndServe(":8088",
nil)
```

```
    if err != nil {
        panic(err)
    }
}
```

- Next, create a new resources/index.gohtml file like the one below:

```
<html lang="en">
<head>
    <meta charset="UTF-8"/>
    <title>go:embed demo</title>
</head>
```

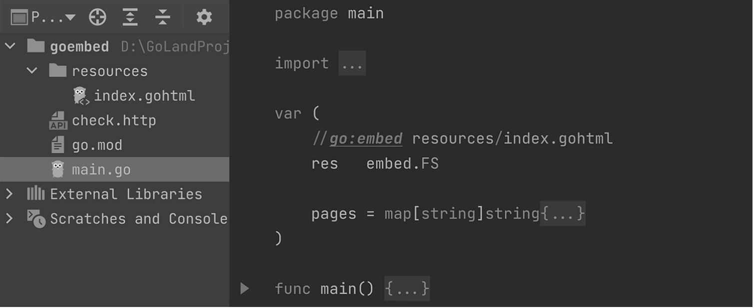
```
<body>
<div>
    <h1>Hello, {{ .userAgent }}!</h1>
    <p>If you see this, then go:embed
worked!</p>
</div>
</body>
</html>
```

- Finally, create a file called check.http at the root of the project. This will reduce the time it takes to test our code by making repeatable requests from GoLand rather than using the browser.

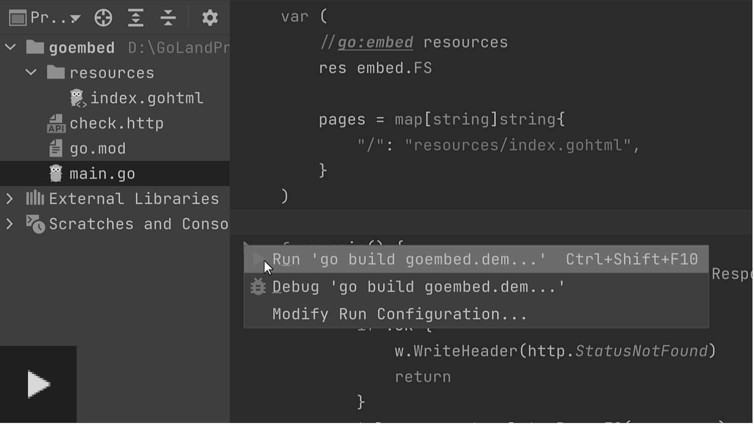
```
GET http://localhost:8088/
```

Note: If you need to, you can download a newer version of Go using GoLand either while creating the project or via Settings/Preferences | Go | GOROOT | + | Download ...

This is how the project layout should look:



If we run this project, then test the request from the check.http file against our server, we get what we'd expect: an HTML response that contains our Hello message and the "Apache-HttpClient" user agent.



At first, this might not look different than any other server responding to a request with our template code.

However, if we change the code in the template without restarting the server, we'll quickly notice that our output will not change unless we rebuild the binary. We can even remove the template, move the binary, or change its running directory, and the result will be similar. How does this work, then?

A quick look at how go:embed works

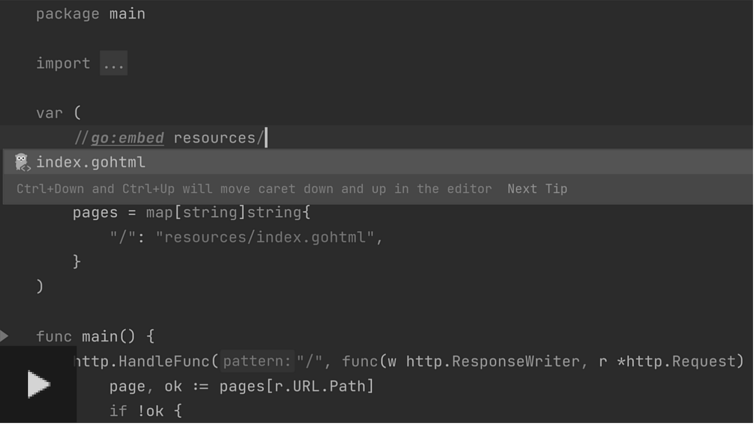
We can isolate a few parts of our code that are involved in using this feature.

We'll start with the imports section, where we can see that we are using a new package called embed. This package, combined with the comment //go:embed, a compiler directive, tells the compiler that we intend to embed files or folders in the resulting binary.

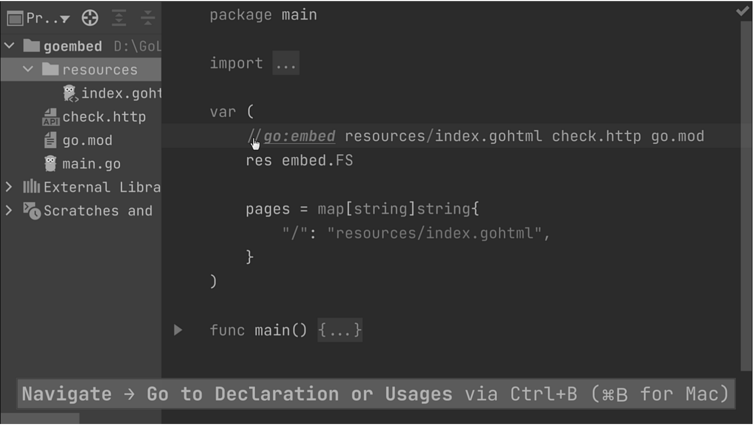
You need to follow this directive with a variable declaration to serve as the container for the embedded contents. The type of the variable can be a string, a slice of bytes, or embed.FS type. If you embed resources using the embed.FS type, they also get the benefit of being read-only and goroutine-safe.

GoLand support for go:embed

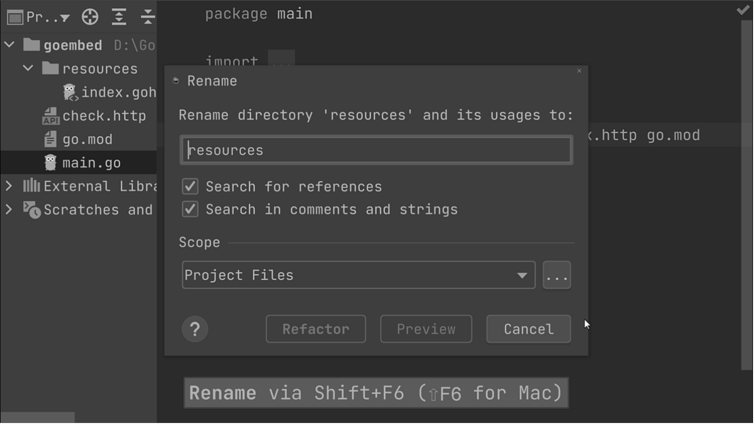
GoLand completion features come in handy while using the embed directive, helping you write the paths/pattern.



You can also navigate to the embedded resource from the editor.



What if you want to change the name of the resource you’ve embedded? Or perhaps you want to change the whole directory structure? GoLand has you covered here too:



Pro tip: You can embed resources into the binary from any file, not just the main one. This means that you can ship modules with resources that are transparently compiled into the end application.

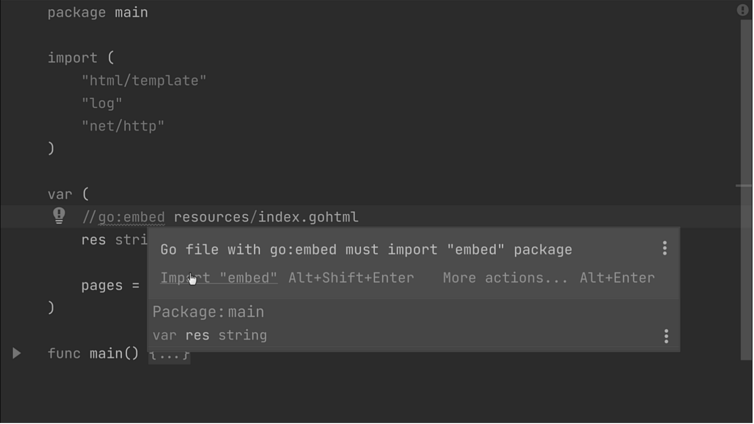
Pro tip: You can use the embedding feature in test files too! Try it out and let us know what you think.

Limitations

Embedding empty folders is not supported. Also, it's not possible to embed files or folders that start with "." or "_". This will be addressed in an upcoming version of Go, thanks to this related issue.

Embedding symlinks is not currently supported either.

If you don’t plan to use embed.FS, then you can use //go:embed to embed a single file. To do so, you must still import the embed package, but only for side effects.

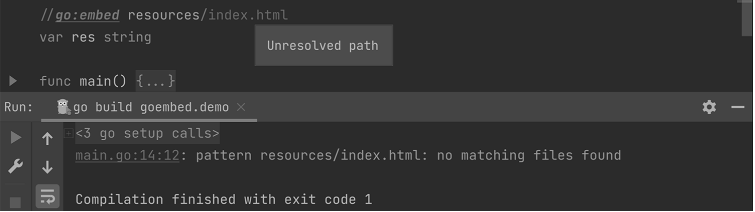


The embedding directive must not contain a space between the comment and “go:“.

```
// go:embed resources/index.gohtml
var res string

//go:embed resources/index.gohtml
var res string
```

The embedded paths must exist and match the pattern. Otherwise, the compiler will abort with an error.



Conclusion

That’s it for now! We learned why and how to use Go 1.16’s new embedding feature, took a look at how it works, and considered some caveats to remember when using it. We’ve also seen how

GoLand helps you work with this feature and provides features such as completion, error detection, and more.

We are looking forward to hearing from you about how you use this feature. You can leave us a note in the comments section below, on Twitter, on the Gophers Slack, or our issue tracker if you'd like to let us know about additional features you'd like to see related to this or other Go functionality.